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Feasibility of a Random Quadrat Study Design to Estimate Changes in Density of Mexican Spotted Owls

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We conducted a "pre-pilot" quadrat sampling study to evaluate the feasibility of a region-wide monitoring program to estimate changes in the density of Mexican spotted owls (*Strix occidentalis lucida*). Based upon capture probability, abundance, and density estimates, we believe the proposed monitoring program to be feasible given the survey protocol provided. We discuss several recommendations for the implementation of the monitoring program.

Keywords: Mexican spotted owl, *Strix occidentalis*, random quadrat sampling, survey protocol, logistics, capture probabilities

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INTRODUCTION

To evaluate the status of the Mexican spotted owl (*Strix occidentalis lucida*), the Mexican Spotted Owl Recovery Team (Recovery Team) has proposed a region-wide monitoring program based on a random quadrat sampling design (USDI 1995). The primary objective of the monitoring program is to estimate changes in owl density over time. A similar quadrat sampling design was originally developed to estimate the density of northern spotted owls in Olympic National Park, Washington (Noon et al. 1993). Information obtained from the monitoring program will be used to determine if proposed delisting criteria have been met and to evaluate the efficacy of management actions (USDI 1995). Therefore, we conducted a "pre-pilot" study using four randomly placed quadrats to evaluate the feasibility of the monitoring program. A full pilot study will be undertaken by the responsible management agencies to determine the sample size needed to reliably estimate changes in density.

Primary objectives of the "pre-pilot" study were to:

(1) obtain a *preliminary* estimate of the probability of detecting and capturing owls ($\hat{p}_k$) to help determine the number and size of quadrats needed to reliably estimate changes in owl density;

(2) evaluate the survey protocol provided by the Recovery Team (amendment to contract no. 53–82FT–4–07); and

(3) identify logistical problems that could affect the successful implementation of the monitoring program.

Secondary objectives of the study were to:

(1) capture and monitor owls detected; and

(2) estimate reproductive output.

METHODS

Quadrat Selection

Quadrat boundaries were delineated by B. Waltermire, National Biological Service, Fort Collins, Colorado, and P. Ward, USFS, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Two quadrats were selected near each of two long-term owl demography study sites, the Gila Study Area (GSA) and the Coconino Study Area (CSA; Gutiérrez et al. 1994). First, 10 random starting points were selected within an 80 km radius of each demography study area. An alternative point was selected if the original point fell on private land or outside an elevational range of 1830–2900 m (a surrogate for owl habitat since vegetation maps were not available). These points provided a beginning point from which a 50 km^2 block could be drawn. The orientation of the 50 km^2 block was allowed to vary in nine directions. This resulted in a total of 90 possible blocks for each area. A block was eliminated if it overlapped with any part of the main demography areas or if >10% overlapped with private land. The two blocks with the greatest number of historical owl sightings were selected from each set of 90 possible blocks. In the event of ties, the two blocks with the greatest amount of area between 1830 m and 2900 m elevation were selected. If ties still remained, the two blocks closest to the main demography study area were selected.

The Escudilla Mountain Quadrat (EMQ) and the Hannagan Meadows Quadrat (HMQ) were associated with the GSA, while the Kendrick Peak Quadrat (KPQ) and the Knoll Lake Quadrat (KLQ) were associated with the CSA. We modified original boundaries a priori on all four quadrats based on

physiographic features to reduce edge effects (White et al. 1982:120–124) since ridgelines influence the location of activity centers (Ganey and Balda 1989). We also modified boundaries on the EMQ and KLQ to encompass more known owl territories. We deemed the latter modifications appropriate since one of the objectives of the pilot study was to determine if the survey protocol promoted the capture and subsequent monitoring of spotted owls.

Quadrat Descriptions

The climate on the quadrats was characterized by cold winters and warm summers. The majority of the precipitation occurred between December and March. Primary land uses were recreation, timber harvesting, and livestock grazing.

Escudilla Mountain Quadrat

The EMQ encompassed 64.2 km^2 and was located in the San Francisco Mountain Range, 6 km north of Alpine, Arizona. Part of the quadrat extended into western New Mexico. The topography was characterized by moderate- to steep-sloped canyons. Elevations ranged from 2196 to 2760 m. Three vegetation communities were present. The first was a mixed-conifer forest, dominated by Douglas-fir (*Psuedotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). White fir (*Abies concolor*), blue spruce (*Picea pungens*), and Gambel oak (*Quercus gambelii*) were also present. The second was a pine-oak forest, dominated by ponderosa pine in the overstory and Gambel oak in the understory. The third was a coniferous woodland, dominated by pinyon pine (*Pinus edulis*) and junipers (*Juniperus spp.*).

Hannagan Meadows Quadrat

The HMQ encompassed 47.4 km^2 and was located in the Blue Range, 24 km south of Alpine, Arizona. A large part of the HMQ was located within the Blue Range Primitive Area, therefore, road access was limited. The topography was characterized by moderate- to steep-sloped canyons. Elevations ranged from 2166 to 2763 m. The only vegetation community was a mixed-conifer forest dominated by blue spruce, Douglas-fir, white fir, and ponderosa pine. The understory was frequently composed of quaking aspen (*Populus tremuloides*) and Gambel oak.

Knoll Lake Quadrat

The KLQ encompassed 56.3 km^2 and was located on the Mogollon Rim, 72 km southeast of Camp Verde, Arizona. The topography was characterized by moderate- to steep-sloped canyons. Elevations ranged from 2100 to 2377 m. The southern portion (approximately 20–30%) of this quadrat experienced a major forest fire in the fall of 1989. Two vegetation communities were present on the KLQ. The first was a mixed-conifer forest dominated by Douglas-fir, white fir, and ponderosa pine. The understory was frequently composed of quaking aspen and Gambel oak. The second was a pine-oak forest dominated by ponderosa pine in the overstory and Gambel oak in the understory.

Kendrick Peak Quadrat

The KPQ encompassed 71.7 km^2 and was located in the San Francisco Peaks, 29 km northwest of Flagstaff, Arizona. Most of the KPQ was located within the Kendrick Mountain Wilderness Area, therefore, road access was limited. The topography was characterized by a large cinder cone surrounded by smaller hills and flat areas. Elevations ranged from 2163 to 3143 m. Two vegetation communities were present on the KPQ. The first was a mixed-conifer forest dominated by Douglas-fir, white fir, and ponderosa pine. The second was an open coniferous woodland dominated by pinyon pine.

Personnel

Eight individuals (two per quadrat) were hired, trained, and supervised by project leaders on the GSA and CSA. They were trained between 23 May and 3 June in the techniques required for night surveying, daytime monitoring (walk-ins), capture, banding, and data recording. Quadrats were examined and survey routes were established between 6 and 10 June. Field work began 13 June. Project leaders closely supervised crews during the field season.

Surveys

We attempted to locate and identify all spotted owls within the four quadrats. Owls were located using vocal imitations of their calls to elicit responses (Forsman 1983). Methods for recording field data were described in Franklin et al. (1986). We conducted four 10-day survey cycles between 13 June and 4 August in which we followed the survey protocol provided by the Recovery Team (USDI 1995). This was followed by an extended survey period ending 17 August. The purpose of the extended survey was

to locate and capture as many individual owls on or near the quadrats as possible. Therefore, during the extended survey we followed the demography study protocol (Gutiérrez et al. 1994) on all four quadrats and expanded the boundaries of three quadrats (the HMQ, KLQ, and KPQ).

Night surveys were conducted to locate general areas of spotted owl activity. We established call stations so that each quadrat was completely surveyed during each cycle. Generally, call stations were placed every half-mile along roads, trails, and drainage bottoms. However, in order to ensure complete coverage, placement of call stations in some cases deviated from this standard (e.g., call points were placed on prominent vistas). Modifications were based on the judgment of the project leaders. We visited each call station once per cycle for a period of 10 minutes. Night surveys were initiated no earlier than 30 minutes prior to dusk and generally ended before 2300.

Following a detection from a call station, walk-in surveys (Franklin et al. 1990) were used to: (1) locate roosts and/or nests; (2) assess reproductive output; and (3) band or resight owls. Two walk-in surveys, one in the morning and one in the evening, were conducted for each night survey detection. The morning walk-in survey was initiated approximately one half-hour before sunrise and the evening walk-in was initiated one half-hour to two hours prior to sunset. One walk-in survey was conducted within 24 hours of the detection, while the second was conducted within a week of the detection.

Capture and Banding

We used several capture techniques including noose poles, mist nets, and bal-chatri traps (Forsman 1983; Bull 1987). A locking aluminum U.S. Fish and Wildlife Service (USFWS) band was placed around a tarsus-metatarsus of each captured owl. A uniquely colored plastic leg band with a colored vinyl tab was placed around the opposing tarsus-metatarsus to facilitate individual recognition (Franklin et al. 1987). Juveniles were marked with a green color band with a central white stripe and an aluminum USFWS band. After an initial physical capture, individual owls could be "recaptured" by resighting the colored leg band. Both crew members were required to independently confirm the band color combination for a valid resighting. Color combinations were not reviewed prior to resighting to reduce potential bias in color recognition.

Reproductive Assessment

Once an individual or pair was located, we attempted to locate nests and juveniles by feeding pair members live mice (*Mus musculus*; Forsman 1983). If an owl consumed or cached four or more mice without bringing one to a nest or juvenile during a walk-in survey prior to 10 July, we assumed that either nesting had not been attempted or had failed (i.e., no juveniles were fledged). If a pair member took less than four mice and did not bring one to a nest or juvenile, we made no conclusion regarding reproductive status.

Sex and Age Determination

Sexes of adult and subadult owls were determined by call and behavior. Males had lower-pitched calls than females, while only females are known to incubate (Forsman et al. 1984). Juveniles could not be sexed accurately based solely on morphological characteristics (Blakesley et al. 1990). The age of individual owls was estimated from plumage characteristics (Forsman 1981). Three general age classes were distinguished: juvenile (<12 months old), subadult (≥12 and <26 months old), and adult (≥26 months old). In addition, subadults were distinguished between first and second year using the characteristics described by Moen et al. (1991).

Statistical Analysis

Estimating Probability of Detection and Capture

We pooled capture histories from all quadrats and used capture-recapture models for closed populations (Otis et al. 1978; White et al. 1982; Pollock et al. 1990) to estimate the single-visit capture probability ($\hat{p}$). A capture required detecting an owl on a night survey *and* capturing it during one of two walk-in surveys during any given cycle. We used program CAPTURE (White et al. 1982) for model selection and to estimate p.

We modeled data twice based on two different capture criteria. For the first analysis, we only used capture histories of those owls that were physically banded (physical captures). Because this approach can result in small sample sizes and low capture probabilities (E. Seaman, pers. comm.), in our second analysis we counted all visual observations during walk-in surveys as captures (visual captures). This approach assumed that owls did not switch territo-

ries and were not replaced during the field season. Since Mexican spotted owls are site tenacious and seldom switch territories during the breeding season (Gutiérrez et. al 1994), we believed that this assumption was met.

For each analysis, the probability of detecting and capturing an owl at least once during k cycles ($\hat{p}_k$) was given by

$$\hat{p}_k = 1-(1-\hat{p})^k$$

(USDI 1995:514), where $\hat{p}$ is the per cycle capture probability. Although variance estimators exist for $\hat{p}$ and $\hat{p}_k$ (G. White, pers. comm.), these calculations were beyond the scope of this study.

We estimated the capture probability for pair members that did not respond during night surveys but were captured during a walk-in survey ($\ddot{p}$) by multiplying their day-time capture probability (number of cycles the owl was captured divided by the number of cycles that walk-ins were conducted for its territory) by the probability of capturing their mate ($\hat{p}$ from program CAPTURE). The probability of capturing the undetected pair member at least once during k cycles ($\ddot{p}_k$) was given by

$$\ddot{p}_k = 1-(1-\ddot{p})^k$$

(USDI 1995:516).

Estimating Abundance and Density

We estimated abundance and density of spotted owls on the quadrats empirically and used capture probabilities as outlined in the Draft Recovery Plan (USDI 1995). For empirical abundance estimates, we tallied the number of owls determined to have activity centers within each quadrat's boundaries. We attempted to avoid double-counting owls by either banding owls or by obtaining repeated observations to delineate an owl activity center. Multiple responses elicited during the field season that were judged to have originated from a single territory (based upon crew members' knowledge of the quadrat) were assigned to either the male or female of that territory using the pitch of the owl's call. For empirical density estimates, we divided the abundance estimate for each quadrat by the quadrat's size.

Abundance (N_i) on quadrat i based on capture probabilities was given by

$$N_i = \dot{n}_i / \hat{p}_k + \ddot{n}_i / \hat{p}_k \ddot{p}_k$$

(USDI 1995:516) where

$\dot{n}_i$ = number of owls detected during night surveys on quadrat i, and

$\ddot{n}_i$ = number of owls detected during walk-in surveys but not night surveys on quadrat i.

No variance estimator exists for N_i; however, one is currently being developed (E. Seaman, G. White, pers. comm.). The density of quadrat i was estimated by dividing N_i by area, a_i.

Identification of Logistical and Protocol Problems

Project leaders and crew personnel were required to take detailed field notes. Work schedules, difficulties in following the protocol, and general logistical problems were recorded. After the field season, protocol and logistical problems were summarized.

We were in regular communication with USFS personnel during and after the field season. Information received was used to examine potential problems that could develop if the USFS implemented the monitoring program.

RESULTS

Surveys

Table 1 summarizes survey effort by quadrat. We were unable to visit each call station once per cycle. For example, some stations that should have been surveyed initially during cycle #1 were not surveyed until the 10-day period allotted for cycle #2. However, except for a few redundant stations that were eliminated after cycle #1, all stations were visited four times during the time allotted for the four-cycle sampling period.

We located 27 adult and subadult owls within quadrat boundaries during the four cycles. Seven owls were located on the HMQ, 11 on the EMQ, two on the KLQ, and seven on the KPQ. One owl was located during the extended survey period outside the KPQ (Appendix A).

Capture and Banding

Over all four quadrats, 59% (16) of adults and subadults detected within the four-cycle period were

Table 1.— Mexican spotted owl survey effort during walk-in and night surveys by quadrat.

	Hours of effort				
	Night surveys		Walk-in surveys		
	hours	%	hours	%	Total
EMQ[1]	30.6	25.8	87.9	74.2	118.5
HMQ[2]	30.5	25.5	89.3	74.5	119.8
KLQ[3]	57.4	56.8	43.6	43.2	101.0
KPQ[4]	68.8	42.9	91.4	57.1	160.2

[1]Escudilla Mountain, Arizona (64.2 km²)
[2]Hannagan Meadows, Arizona (47.4 km²)
[3]Knoll Lake, Arizona (56.3 km²)
[4]Kendrick Peak, Arizona (71.7 km²)

physically captured (Appendix A). Including the extended survey period, 68% (19) of adults and subadults were physically captured. Ninety-six percent (26) of adults and subadults were visually captured within the four-cycle period. Including the owl located in the extended survey, 96% (27) of adults and subadults were visually captured.

Reproductive Assessment and Sex and Age Determination

We were only able to estimate reproductive output at three territories. Two juveniles were located at a single territory on the EMQ. Pairs at the other two territories failed to fledge young.

Of 27 adult and subadult owls located within the quadrats' boundaries during the four cycles, 15 were male and 12 were female. Of 19 owls (11 males, eight females) successfully aged, only three were subadults (one male, two females). We could not visually determine the age of nine owls not physically captured. The EMQ, KLQ, and KPQ had one subadult each. We located 12 pairs, three single males, and no single females.

Capture Probabilities, Abundance, and Density Estimates

Using physical captures and band resights, model M_0 was the most appropriate model. We estimated that $\hat{p} = 0.30$, $\hat{p}_k = 0.76$, and $\ddot{p}_k = 1.00$. Using visual captures, model M_h was the most appropriate model. In this case, we estimated that $\hat{p} = 0.54$, $\hat{p}_k = 0.96$, and $\ddot{p}_k = 1.00$. By pooling data across quadrats, we estimated an empirical abundance of 27 owls and an empirical density of 0.12 owls/km^2. Abundance estimates by quadrat were generally higher than abundance estimates derived from previous USFS surveys in the same areas (Table 2).

Using estimates of $\hat{p}_k$ and $\ddot{p}_k$ based on physical captures, we estimated total abundance to be 35.5 owls and total density to be 0.15 owls/km^2. Using the estimate of $\hat{p}_k$ and $\ddot{p}_k$ based on visual captures, we estimated total abundance to be 28.1 owls and total density to be 0.12 owls/km^2 (Table 3 shows abundance and density estimates by quadrat).

Potential Protocol Problems

We identified the following potential problems with the protocol used in this study (USDI 1995):

(1) the requirements of detecting an owl at night before it can enter the capture matrix and allowing only two walk-in surveys per night-survey detection

Table 2.—Comparison of Mexican spotted owl information before and after quadrat sampling.

	Prior knowledge (USFS)		Quadrat results	
Quadrat name	Owls	Territories	Owls	Territories
EMQ[1]	9	5	11	6
HMQ[2]	4	2	7	4
KLQ[3]	4	2	2	1
KPQ[4]	2	1	7	4

[1]Escudilla Mountain, Arizona (64.2 km²)
[2]Hannagan Meadows, Arizona (47.4 km²)
[3]Knoll Lake, Arizona (56.3 km²)
[4]Kendrick Peak, Arizona (71.7 km²)

Table 3.—Empirical and model estimates of Mexican spotted owl abundance and density (in parentheses) by quadrat.

	EMQ[1]	HMQ[2]	KLQ[3]	KPQ[4]
Empirical	11.0 (0.17)	7.0 (0.15)	2.0 (0.04)	7.0 (0.10)
C-R1[5]	14.5 (0.23)	9.2 (0.19)	2.6 (0.05)	9.2 (0.13)
C-R2[6]	11.5 (0.18)	7.3 (0.15)	2.1 (0.04)	7.3 (0.10)

[1]Escudilla Mountain, Arizona (64.2 km²)
[2]Hannagan Meadows, Arizona (47.4 km²)
[3]Knoll Lake, Arizona (56.3 km²)
[4]Kendrick Peak, Arizona (71.7 km²)
[5]Capture-recapture model using only owls that were physically captured after a night survey detection
[6]Capture-recapture model using owls located visually after a night survey detection

resulted in a smaller sample size than would have been possible without these constraints; and

(2) our ability to complete the sample cycles in the allotted time was compromised by campers at survey stations, forest fires, limited road access, and requiring night surveys to end by 2300.

Potential Logistical Problems

We identified the following potential logistical problems:

(1) delayed hiring of personnel due to late funding;

(2) delayed purchasing of needed equipment due to delayed funding and unavailability of supplies;

(3) complication of early surveys due to inappropriate placement of original quadrat boundaries;

(4) low banding success (relative to banding success on the demography projects) due to inexperienced crews;

(5) less effective personnel management because of the isolation of crews;

(6) potential increase in cost if USFS pay requirements are implemented; and

(7) transportation delays because of inclement weather, poorly maintained roads, and lack of four-wheel drive vehicles.

DISCUSSION

The results from the pre-pilot study indicated that the region-wide monitoring program to estimate annual changes in owl density would be feasible. The similarity in density estimates between three of the quadrats (the EMQ, HMQ, and KPQ) and the two demography study areas (Gutiérrez et al. 1994) indicated that the protocol was successful in terms of locating owls. Furthermore, single-visit capture probabilities were reasonable for a capture-recapture study (0.30 or 0.54 depending on capture criteria; see White et al. 1982:50).

The quadrat study resulted in new Mexican spotted owl information even though previous USFS surveys had been previously conducted within the quadrat boundaries. The discrepancy between the quadrat study detections and the USFS detections could have been the result of an increase in the number of territories on the quadrats or a difference in survey intensity and/or protocol. For the former to have occurred, the number of owl territories would have had to increase by 50%. Such a change has not been documented for Mexican spotted owls (Gutiérrez et al. 1994) and was therefore unlikely. On the Apache-Sitgreaves National Forest, USFS spotted owl surveys generally covered only areas of "suitable" habitat (T. Meyers, pers. comm.). This surveying method probably missed owls near the edge of suitable habitat or in areas not defined as suitable habitat. In addition, the USFS Region 3 monitoring protocol exempts additional surveying within a 405 hectare area of known nests/roosts (USFS 1990). On three occasions, we located two territories in an area that the USFS had believed to be occupied by a single pair. Because of the influence of topography on owl territory procurement and defense, this survey criteria is probably not appropriate for Mexican spotted owls.

We conducted our analyses with the understanding that our sample sizes were small and probably inadequate to reliably estimate model parameters. However, preliminary capture probability, abundance, and density estimates could help determine the number of quadrats required to estimate changes in owl densities over time. In addition, we felt that modeling capture histories would help to assess limitations of the proposed sampling design (see Protocol Considerations below).

Although empirical and modeled density estimates are presented without error terms, the KLQ appeared to have a considerably lower density than the other three quadrats. This may have been due to the KLQ's relatively limited elevation range or to a fire that burned a large area within the quadrat in 1989. The HMQ and KPQ contained high proportions of primitive and wilderness areas, which could account for their relatively high densities when compared to the KLQ.

We encountered several potential problems that will need to be addressed to ensure the success of the monitoring program. Because increasing the sampling intensity requires increasing money and personnel investments, some of the problems we identified will be amplified as sample size increases.

Protocol Considerations

Small Sample Size

Using visual captures resulted in 22 owls being included in the capture matrix versus only eight when physical captures were used. Therefore, abundance and density estimates based on visual captures will probably have lower variances than estimates based on physical captures. Using only physical cap-

tures when estimating $\hat{p}$ and $\hat{p}_k$ may require considerably more quadrat samples.

Using visual captures resulted in a higher $\hat{p}_k$ than did using only physical captures. As expected, visual captures resulted in lower abundance and density estimates than did physical captures. Abundance and density estimates using $\hat{p}_k$ based on visual captures were more similar to empirical results than were estimates using $\hat{p}_k$ based on physical captures.

Completion of Sampling Cycles

Occasionally, crews were forced to begin the next cycle before all the call stations had been completed for the previous cycle. Reasons for these delays included campers at call stations and forest fires. Cycle overlap can complicate combining results from different quadrats. A longer field season (i.e., 3.5 months as recommended by the Recovery Team) will allow more time (approx. 18 days) for each survey cycle and should minimize these problems.

Some quadrats regularly required more than 10 days to complete each cycle. Reasons included limited road access and the requirement to end night surveys by 2300. Extending the length of cycles should eliminate delays caused by limited road access. We also suggest allowing night surveys until 2400. Since night surveys generally started around 2000, this additional hour represents approximately a 20% increase in potential survey time.

A trade-off exists between the amount of time allowed for night surveys and the reliability of night survey locations because the later a bird is detected the further it could be from its activity center. However, in our experience, the distance an owl travels from its roost before midnight is variable and responses before 2400 are not necessarily unreliable. If survey cycle lengths are expanded to 18 days (3.5 months/field season), surveying after 2300 probably will be unnecessary.

Although crews had difficulty completing all the call stations within a survey cycle, they were able to complete the pre-pilot study within the 1.75 month time-frame. The KPQ was the largest of the quadrats (71.7 km^2), included four territories, and was completed without any difficulty. The HMQ was the smallest of the quadrats (47.4 km^2), included four territories, and was completed on the last day of the field season. For the monitoring program, quadrat sizes should be conservative to ensure that all quadrats will be completely surveyed four times. Therefore, we based our recommendations for quadrat size on projections from the HMQ. If a 3.5 month field season spans four cycles, we recommend an upper size limit of 75 km^2. We believe a 100 km^2 area could require more than 3.5 months to completely survey four times.

Logistical Considerations

Hiring Dates

Since the success of the region-wide monitoring program will depend on the competence of field crews, advertising position openings and hiring personnel as early as possible is critical. Positions should be announced by November and filled by mid-February. Most qualified personnel will have applied for seasonal employment elsewhere and accepted other positions by May. Therefore, funding should be confirmed well in advance of the field season.

Delayed Purchasing of Equipment

Equipment and supplies (e.g., altimeters and capture equipment) generally required 4–8 weeks for delivery and some assembly prior to use. However, some specialized equipment (e.g., mist nets) may take several months to procure. This equipment will be necessary for the training period and should be ordered well in advance of the proposed starting date.

We had considerable difficulty obtaining an adequate supply of mice for bait. Orders usually needed to be placed several weeks prior to delivery dates. Because a reliable supply of mice will be essential for capture attempts and assessing reproduction, establishing an "in-house" supplier may be necessary. We estimated that 4,000 mice would be required for 25 quadrats each field season.

Adjusting Quadrat Boundaries

If the region-wide monitoring program will depend on stratifying the random quadrat samples by habitat (USDI 1995), a region-wide GIS database will need to be developed that includes vegetation cover types and elevation data. Since it is imperative that all quadrats are located in the intended habitat, quadrat locations should be determined and examined well in advance of the field season. Adjusting boundaries of inappropriately selected quadrats during the early stages of the field season can complicate early surveys and disrupt the sampling frame. Adjusting quadrat boundaries to reflect topographic features (USDI 1995) also should be done well in advance of the field season.

Banding Success

We agree with the management structure proposed in the Recovery Plan. However, the presence of seasonal crew leaders with experience banding spotted owls would considerably increase banding success and thus capture probabilities. We recommend having one seasonal crew leader per five quadrats. These crew leaders could spend a standardized amount of time (e.g., 2–4 walk-in surveys per cycle) on each quadrat and help crews band owls. Increasing capture probabilities could reduce the number of quadrats needed to reliably estimate changes in density. On the four pre-pilot study quadrats, project leaders were present during nine of 16 captures.

A 10–15 day training period will be needed to train crews to find owls, conduct surveys, and record data properly. However, 10–15 day training periods will not necessarily provide sufficient banding experience because of the lack of available unbanded birds. For example, on the GSA and CSA, most adult and subadult owls had been banded before the training period. If possible, crews should be trained using owls from Management Territories since most will be unbanded.

With regular supervision from seasonal crew leaders, two walk-in surveys per detection, as recommended by the Recovery Team, should be adequate to band most owls during a field season. Allowing >2 walk-in surveys per detection would increase banding success, but would result in longer cycles. For example, on the HMQ, if four walk-in surveys were allowed per detection, there would have been two cycles with 24 walk-ins.

Personnel Management

As a whole, our personnel were dedicated, hardworking, and honest. However, if 50 crew members will be needed for 25 quadrats, some employees will inevitably handle their duties unprofessionally. Unmotivated and/or dishonest crew members will collect unreliable data. We recommend a careful screening process to select the most qualified and motivated applicants. Priority should be given to applicants with spotted owl experience that receive good written recommendations. Replacement personnel, available on short notice, will be needed to replace crew members who are injured, terminated, or resign.

The training period should be used to gauge personnel dynamics, and assignments should be made accordingly. Problems between crew members that remain undetected may affect the quality of field work. In addition to increasing capture probabilities, frequent visits by the seasonal crew leaders would increase awareness of and provide solutions to personnel problems. We found that two visits per 10-day cycle by project leaders helped minimize such problems.

Some field assistants voiced a feeling of uncertainty regarding the ultimate goals of the study and the management application of their work. We were furnished with a copy of the Recovery Team amendment to contract 53-82FT-4-07 prior to the field season. However, this protocol explained the goals and objectives of the study only briefly. In the future, each crew should be provided with the quadrat sampling monitoring procedures written by the Recovery Team (USDI 1995). This detailed document will give the crews a better understanding of their work and incentive to do their jobs well.

Cost Analysis Related to Personnel

[Note: USFS pay rates and regulations were supplied by H. Green (pers. comm.) and P. Morrison (pers. comm.).]

The workload and work scheduling required by the survey protocol will affect the cost of implementing the region-wide monitoring program. Our field crews were restricted only by the guidelines outlined in the protocol, which were developed to ensure efficient and standardized surveying. We set no additional restrictions regarding the time of day the crews worked or the number of hours they worked per day or week.

Seasonal USFS personnel in the Southwest are not limited to working a certain number of hours or during certain times of the day. However, overtime and differential pay are mandatory. For example, all USFS personnel who work before 0600 or after 1800 receive night differential pay (regular pay plus 10%). Overtime pay is time-and-a-half while holidays are double-time. Three possible work schedules exist for USFS personnel: regular, flex, and first 40. The first 40 and flex schedules are currently used by USFS spotted owl survey crews. Under the first 40 schedule, personnel receive overtime pay after the first 40 hours they work in a week (no set schedule). Under the flex schedule, personnel receive overtime pay after the first 80 hours they work within a two-week period (schedule set by their supervisor) and receive daily overtime pay if they work over 11.5 hours. The USFS budgets a planning rate based on the GS level of the employee in question. GS-4 level personnel are

budgeted $9/hour and GS–5 level personnel are budgeted $10/hour. This amount includes benefit and insurance costs.

Our crews rarely worked more than 11.5 hours in a day, but on the average worked about 25 hours per five-day period before 0600 or after 1800. Under USFS policy, this effort would have entitled them to 25 hours of regular pay plus 10%. If the field season is 3.5 months long, overtime should be minimal.

Each crew member received $50 per month in housing subsidies to encourage them to live near their particular quadrat. They received no per diem for nights they stayed in the field. USFS personnel receive up to $26 in per diem pay depending on how long they are away from an official duty station. Because of the remote location of most owl territories on our quadrats, returning to a duty station each night would not have been feasible.

We agree with the proposal in the Recovery Plan that having crews input their own data would increase their concern for doing quality research. We estimate that entering data, which would probably be done during the middle of the day, would take 1–2 hours per day spent in the field. If four cycles are implemented over 3.5 months, crews should have time to enter the data and examine trends without overtime wages being required. Otherwise, keeping crews apprised of their progress may be accomplished by having crews turn in completed data forms and receive feedback from crew leaders.

Although USFS personnel are not subject to limitations as to when or where they can work, for example off-trail and/or in the dark, dangers associated with this kind of work are important to consider. If quadrats are placed in remote, roadless, and/or steep mountain ranges such as the Chiricahua Mountains, we believe restrictions should be implemented to minimize the chance of injury. Such restrictions should vary by quadrat location and be decided upon by project leaders familiar with the area.

Transportation

Poor road conditions and late-summer rains made driving conditions difficult for light two-wheel drive trucks. Unreliable transportation can make completing survey cycles within 10 days difficult or impossible. Reliable four-wheel-drive vehicles will be needed. USFS vehicles cost approximately $200/month plus 18¢/mile (H. Green, P. Morrison, pers. comm.). Vehicles can also be rented from rental agencies for a minimum of $600 per month (and usually much more). Replacement vehicles will be needed in case major repairs are required.

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APPENDIX A

Summary of Survey Results for the Four Quadrat Samples

The following is a summary of results for the four Mexican spotted owl quadrat studies in New Mexico and Arizona.

Legend:		
	N = night surveys	Cycle 1: 13June–23 June
	D = walk-in	Cycle 2: 27 June–7 July
	R = vocal response	Cycle 3: 11 July–21 July
	V = visual capture	Cycle 4: 25 July–4 August
	C = physical capture	Ext: 5 August– 17 August

Escudilla Mountain Quadrat

Territory/	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Ext
Sex	N	D	N	D	N	D	N	D	
EMQ 1									
male		RV		RV	R	RVC	R	RVC	
female	R	RV	R	RV		RVC			
EMQ 2									
male	R	R					R	RV	
female								RVC	
EMQ 3									
male	R	RV	R	RV	R	RV	R	RV	C
female		RV		RV		RVC	R	RV	
EMQ 4									
male	R	RVC					R	RVC	
female		RVC							
juv #1		RVC						RVC	
juv #2		RVC						RVC	
EMQ 5									
male			R	RV					
EMQ 6									
male	R	RV	R	R	R	RV			C
female				R					

Knoll Lake Quadrat

Territory/	Cycle 1		Cycle 2		Cycle 3		Cycle 4		Ext
Sex	N	D	N	D	N	D	N	D	
KLQ 1									
male	R	RVC	R	RV	R	RVC	R	RVC	
female		RV	R	RV		RVC		RVC	

Hannagan Meadows Quadrat

Territory/ Sex	Cycle 1 N	Cycle 1 D	Cycle 2 N	Cycle 2 D	Cycle 3 N	Cycle 3 D	Cycle 4 N	Cycle 4 D	Ext
HMQ 1									
male	R	RV			R	RV	R	RV	
HMQ 2									
male	R	RV	R	RV	R	RV	R	RV	
female		RV		RVC				RVC	
HMQ 3									
male	R	RV	R	RV	R	R	R	RV	
female		R	R	RVC	R	R	R	R	
HMQ 4									
male	R	RV	R	RV	R	RV	R	RVC	
female	R	RV	R	RV		RVC		R	

Kendrick Peak Quadrat

Territory/ Sex	Cycle 1 N	Cycle 1 D	Cycle 2 N	Cycle 2 D	Cycle 3 N	Cycle 3 D	Cycle 4 N	Cycle 4 D	Ext
KPQ 1									
male	R	RVC			R	RV			RV
female		R				RV			
KPQ 2									
male	R	RV	R	RVC	R	RV	R	RV	
KPQ 3									
male	R	RVC	R		R		R	RV	
female		RVC					R	RV	
KPQ 4									
male	R		R	RV	R	RV	R	RV	RV
female			R	RV	R	RV	R	RV	RV
KPQ 5[1]									
male									RVC

[1]*located outside of original quadrat boundaries*

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Rocky
Mountains

Southwest

Great
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